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Behavior towards health risks: An empirical study using the "Mad Cow" crisis as an experiment

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Abstract The paper exploits the "Mad Cow" crisis as a natural experiment to gain knowledge on the behavioral effect of new health information. The analysis uses a detailed data set following a sample of households through the crisis. The paper disentangles the effect of non-separable preferences across time from the effect of previous exposure. It shows that new health information interacts in a non-monotonic way with disease susceptibility. Individuals at low or high risk of infection do not respond to new health information. The results show that individual behavior partly offsets the effect of new health information.

Keywords Health risks · Health behavior · Intra-household decision

JEL Classification D1 · D8 · C3

On March 20, 1996, the British Minister of Health informed the House of Commons that scientists had established a link between the "Mad Cow"

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disease, (bovine spongiform encephalopathy [BSE, hereafter]) and the new variant Creutzfeldt–Jacob disease (nvCJD), a fatal brain disease which affects humans. The disease could pass from cows to humans, by consumption of infected beef. At that date, eight people out of the ten diagnosed with the nvCJD in the UK had died. This information was immediately reported by the French media, and came as a shock, as beef is traditionally an important part of French diet. As consumers panicked, the demand for beef dropped by 26% within a few weeks.

In this paper, we use this "natural" experiment to study the non-monotonic relationship between risk taking behavior and past consumption of risky goods. It can be seen as a natural experiment that shifts the level of perceived mortality risk and reveals differences in susceptibility to the disease. The paper investigates several issues: (1) Does new information on disease susceptibility affect health behavior? (2) Are those at risk most likely to take preventive actions to reduce exposure? (3) How do those at low risk respond to new health information? (4) How is health information processed within a household? And more particularly, how do different members influence the decision to move towards safer behavior?

Previous work in this area has been limited because of the difficulty in disentangling the effect of new information and self-selection into risky behavior. For an extensive review of the economic literature on health behavior and risks, we refer the reader to Viscusi (1993) and the references therein, especially Viscusi, Magat and Huber (1987), Viscusi and Moore (1989), Viscusi (1990) or Viscusi (1997).

The "Mad Cow" crisis has many ideal features. The information came in a very sudden way and was almost impossible to anticipate. This means that consumers were already at risk, without knowing it, so we can rule out self-selection based on this information. One can argue that individuals who engage in smoking, drinking or who chose a risky job usually understand that there is an element of risk. Evaluating the effect of health information using data on such behavior will be biased by their possible self-selection.[1]

If consumption prior to the crisis is observed, the econometrician has as much information as the consumer on the susceptibility of nvCJD. We have in this case a clear *idiosyncratic* measure of differences in how much at risk the agents are when new health information is released. This allows us to link health behavior to idiosyncratic differences in disease susceptibility. This is also unusual in this literature because of a lack of panel data on behavior and clear unexpected variations in risks.

The paper uses a unique panel data set which follows for a long period the consumption of households before and after the crisis. We relate their consumption behavior to their prior exposure to beef, a proxy for their susceptibility of developing nvCJD in the future. We develop a flexible model of health behavior which allows for unobserved heterogeneity in preferences

[1] The self-selection has been pointed out by Farrell and Fuchs (1982) and Viscusi and Hersch (2001) for instance in the case of tobacco.

and non-separability in preferences over time. We control for a number of individual characteristics, including other risky habits, which may be correlated with past choices. We show that the interpretation of the results are robust to a number of alternative explanations.

Overall, the results show that providing individuals with an indication of their susceptibility to fatal diseases has complex consequences. Behavior towards health depends on the susceptibility to a fatal disease in a nonlinear way. Individuals with low susceptibility ignore new health information and do not alter their behavior. Individuals at high risk respond in a similar way. Individuals at medium risk curb their risk taking behavior, but do not completely abandon it. Hence, individual behavior can partly offset potential medical gains obtained from better knowledge. However, on aggregate, health behavior improved as consumption fell. If the focus of the government is tackling health inequalities, a policy which provides more information on disease susceptibility may actually increase it.

Section 1 presents the data set and documents the heterogeneity in the response to the crisis. Section 2 presents a dynamic model of risk taking behavior and discusses identification issues. The model is then confronted with the data and we test different explanations of the effect of previous exposure to beef in Section 3. Section 4 concludes.

1 Data and descriptive statistics

1.1 Overview of the "Mad Cow" scare

On March 20, 1996, the British Minister of Health informed the House of Commons that scientists had established a link between the "Mad Cow" disease, and the new variant Creutzfeldt–Jacob disease, a fatal brain disease which affects humans. The disease is triggered by the accumulation of a prion protein in the brain. The prion passes from cows to humans, by consumption of infected beef. At that date, eight people out of the ten diagnosed with the nvCJD in the UK had died. By 1996, a large number of cows had been infected with BSE and, given the incubation time, a number of them had entered the food chain undetected. Before March 1996, nvCJD was totally unknown in the wider public and BSE was still a specific bovine disease, not unlike scrapie, which had affected sheep for more than a century, without effects on humans.

The "Mad Cow" crisis made the headlines of most newspapers for several months and came as a shock, as over 98% of French households had consumed beef prior to that date. An embargo on British beef was imposed shortly after, but the media reported numerous cases of frauds. At that time, BSE had also been diagnosed in French cattle.

At the time of the crisis, few scientific facts were known for certain. Consumers were informed that the consumption of infected beef was the determinant of nvCJD, as those who had been diagnosed had on average consumed large amounts of beef. The exact incubation period in humans was not known, but was thought to be around a couple of years. The exact dose-response relationship was also unknown at the time and has not been firmly established in the medical literature yet. Alarmist (but imprecise) forecasts of the future death toll were published. Predictions as high as 500,000 deaths in the UK were put forth (The Economist, March 30, 1996, p. 25).

1.2 The data set

The panel data set has been collected by SECODIP, a French firm which gathered data for marketing purposes on a sample of representative households. It recorded all expenditures for a representative sample of 2,798 French households, week by week, between January 1, 1995 and June 24, 1996 (76 weeks).[2] The data was recorded using bar code scanners and measurement error is likely to be small.

Each week, the household reported each item bought with a detailed description of the product, the quantity and the expenditure. The items under consideration are all purchases of meat, fish, eggs and dairy products. The information about the product is quite detailed, describing the particular cut of meat or the type of fish (18 different cuts of beef are reported). The data has been aggregated up at a quarterly frequency, in order to avoid zero expenditure due to infrequent purchases. This leaves six periods, the crisis starting at the beginning of the last quarter.

In addition, in 1995 only, the data set recorded all purchases of alcohol on a weekly basis. The data set also reports details on the composition of the family, the age of all the members, their occupation and education level, the household income, the region of residence and the size of the city. The data set also reports anthropometrical measures for all the household members such as height and waist circumference. All these household characteristics are reported at the start of the period, so we observe no variation during these 76 weeks. We construct a measure of alcohol consumption by averaging all alcohol purchases over the 52 weeks of 1995 and by scaling it by the number of adults in the household. We then break down this variable into three dummies at the 33rd and 66th percentile. We also construct a ratio between waist circumference and height to measure whether any household members are overweight. We break down this variable into three dummies in the same way as alcohol consumption.

Tables 1 and 2 present summary statistics. On average, the consumption of beef fell sharply by about 26% in quantities and by 22% in expenditures when households learned about the crisis. During that period, the relative price of beef fell slightly by about 2%. From the aggregate price index, the crisis is barely noticeable. This may be the effect of the European Union policy of

[2] Consumers learned about the crisis on March 20, 1996, so their reactions to the news are observed during 13 weeks. This is enough to study their immediate reaction but not longer term behavior.

Table 1 Descriptive statistics

	Before crisis	During crisis
Quantity of beef	190 (190)	140 (200)
Quantity of beef, conditional on buying	400 (470)	350 (370)
Number of purchases of beef, weeks 12–24	5.9 (3.5)	4.9 (3.5)
Expenditure on beef	1.67 (1.62)	1.31 (1.60)
Total expenditure on animal protein	6.36 (4.80)	6.55 (4.93)
Relative price of beef	1	0.98

Standard deviations in parenthesis. All quantities are expressed in grams per capita and per week. All expenditures are expressed in euros per capita and per week.

price stabilization, which allows storage and destruction of surplus. These facts imply that consumers changed to more expensive types of meat, a fact that we investigate in more detail in Section 3. Households did not change their total expenditure on animal protein (which includes all meat and fish expenditure), which is slightly higher during the last period. This means that they substituted towards other types of meat or fish.

1.3 Heterogeneity in behavior when new information is available

Tables 1 and 2 only give an aggregate view of the behavior as a result of new health information. We now study the heterogeneity in the response to new information, using the cross-section dimension of the data set.

Figure 1 displays a measure of the change in quantities between two periods (quarters). If c_{Bt} is the per capita quantity of beef consumed in quarter t, the measure is $100 * (c_{Bt} - c_{Bt-1})/(c_{Bt}/2 + c_{Bt-1}/2)$, which is bounded between -200 and 200. Two distributions are displayed, before and after the announcement.

Before the announcement, the change in consumption is centered around zero with a roughly symmetric distribution. The distribution after the an-

Table 2 Descriptive statistics (fixed characteristics)

Fixed characteristics			
Mean age of head	53.6 (14.9)	Household size	2.84 (1.35)
% Households with children	0.36 (0.48)	College degree	0.04
Head farmer	0.05	Head self-employed	0.06
Head manager	0.17	Head white collar	0.27
Head blue collar	0.41	Head no activity	0.04
Live in village	0.34	Live in medium town	0.18
Height, women	1.61 (0.62)	Height, men	1.73 (0.65)
Waist circumference, women	0.98 (0.09)	Waist circumference, men	0.92 (0.09)
Ethanol purchase in 1995 (liter per capita, per week)	0.11 (0.17)		

Standard deviations in parenthesis. All quantities are expressed in grams per capita and per week. All expenditures are expressed in euros per capita and per week. Height and circumference are in centimeters.

Fig. 1 Change in beef consumption, before and during the announcement. *Note*: Data source: SECODIP panel data

nouncement is different and interesting for two reasons. First, the distribution is centered to the left and asymmetric, because most households have decreased their consumption. Second, there is a strong heterogeneity in households' responses in terms of consumption changes. There is a *continuous* distribution over the consumption changes. Some households have decreased their consumption by 20, 50 or 80%. This means that the households were not faced with a discrete decision: either stop risky behavior or ignore new health information. This result is not due to the aggregation of different behavior within the household, as it holds also for single person households. The decrease in beef consumption is the result of consumers purchasing less often and fewer quantities. Even the average quantity of beef purchased, conditional on purchasing some, has decreased significantly.

About 8% of the sample stopped consuming beef altogether. This figure is higher than the 3.5% in the preceding periods, but still relatively low with regard to the crisis, as the households could substitute to other types of meat or animal protein. Note that some households have increased their consumption, despite the crisis. Part of the increase could be explained by relative price variations, as the price of beef slightly decreased after March 1996.

The distribution of total expenditure on animal protein did not change as a consequence of the crisis. In particular, there is no evidence that any households became vegetarian.

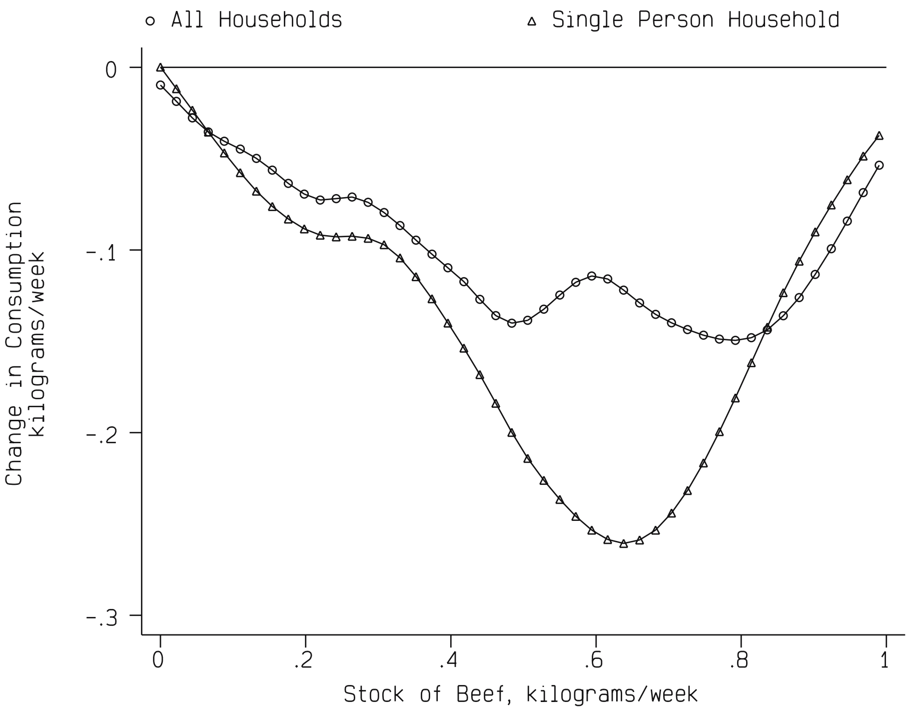

Fig. 2 Effect of prior exposure to beef on change in consumption. *Note*: Data source: SECODIP panel data

1.4 Changes in behavior and susceptibility to CJD

In this section, we analyze the heterogeneity in changes in beef consumption as a function of past behavior. We correlate changes in quantities consumed as a result of the crisis with the average consumption calculated up to the crisis (weekly average per quarter). Figure 2 displays a non parametric regression using a grid with fifty points. The figure plots the response of all households in the sample as well as single person households.[3]

There is a correlation between changes in health behavior (as indicated by further consumption of beef) and disease susceptibility (proxied by past consumption). The response is U-shaped. Households with either small or large consumption prior to the crisis demanded less beef. This fact is even more pronounced for individual consumption as measured for single person households. A formal statistical test shows that both minor and substantial consumers of beef reduced their consumption statistically less than moderate consumers of beef (the associated F tests are equal to 40 and 43, respectively).

[3]The figure was produced with a roughness penalty method. See Green and Silverman (1994) and Chesher (1997) for an application. We experimented with different roughness penalties and settled for a value of 15 which produced a smooth enough graph and preserved the shape of the data.

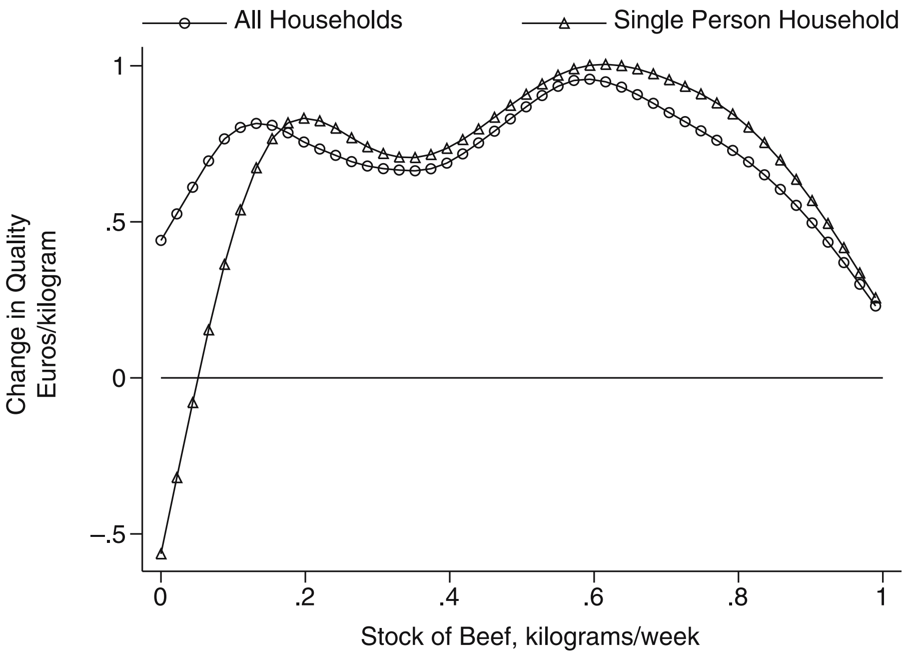

Fig. 3 Effect of prior exposure to beef on change in quality. *Note*: Data source: SECODIP panel data

The previous graph assumed that consumers could only respond to new health information along one dimension, the consumed quantities. In reality, individuals can also choose better quality products. Analyzing only quantities could lead to misleading conclusions.[4]

We now analyze how consumers responded to the crisis in the *quality* dimension and how the demand for quality differed with prior behavior. In France, at the time of the crisis, the main quality differentiation was the cut of the beef and not the origin.[5] The data on quantities and expenditure per item were used to compute unit prices, i.e. the price per gram. The variation in prices paid by a household reflects both time and regional variations but also the quality of the product. We therefore compute a quality index by computing the residuals from a regression of unit prices (prices per gram) on time and regional indicators.

[4] Adda and Cornaglia (2006) document a related trade-off for tobacco consumption.

[5] The country of origin of the beef was not recorded, because, up to 1997, it was not legal to reveal the country of origin to the consumer for "fear of distortions" on the beef market. Yet, shortly after the crisis, the French retail industry set up a label on domestic beef, which was assumed to be safer than foreign beef. In April 1996, the consumer had then the choice between French and foreign beef, but the precise origin of the foreign beef was not indicated. At the time of the crisis, French cows had also been diagnosed with BSE, so it is not clear whether the label was very meaningful. There is no indication that the introduction of this label changed the aggregate demand for beef.

As seen in Table 1, the relative price of beef fell by 1.6%. In the data set, we find the same pattern for a given cut of beef. However, the average price *paid* by households in the data set for beef increased sharply as a result of the crisis, by about 10%. This indicates that the households went out for more expensive cuts of beef after March 1996. From the data, the market share of low quality cuts of beef did sharply decrease during the crisis, while the demand for high quality cuts of beef increased.[6]

The crisis triggered both a decrease in the consumption of beef and an increased demand for higher quality. This increased demand for quality regarding beef consumption was not uniform across households. Figure 3 displays the change in the demand for quality between the quarter preceding the crisis and the quarter after the announcement as a function of the previous exposure to beef, both for all households and for single person households. The response is hump shaped as both households with low and high exposure to beef did not change their behavior in terms of quality.

The responses in Figs. 2 and 3 do not condition on observable characteristics which could potentially confound these results. The next section presents a model which summarizes different explanations and then shows how to discriminate between them.

2 Model and econometric specification

2.1 A model of risky consumption

The facts described in the previous section can be explained in at least three different ways. First, although consumers seemed to respond to new health information about nvCJD, there might be heterogeneity in how individuals value their health. Some individuals might have low concern about their health and hence select themselves into risky behavior. These individuals might also consume larger quantities of beef even before the crisis.[7] This would result in high stock consumers decreasing less their consumption of beef when they learn about the crisis.

Second, preferences might be non-separable across time, for instance in the case of habit formation. Therefore, some individuals might have more difficulties in adjusting their consumption in the short run. This would introduce a correlation between past consumption and adjustment patterns during

[6] With hindsight, this does not appear to be a rational behavior as these cuts are closer to the spine and therefore more likely to lead to contamination. However, at the time of the crisis, there was not extensive knowledge about the transmission of the disease, especially among consumers.

[7] In France, the awareness of a link between beef, cholesterol and coronary heart diseases (CHD) is lower than in many other countries. France has the lowest rate of CHD in the world together with Japan. The rate is about three times lower than in the USA, and four times lower than in the UK. The consumption of beef is mostly determined by cultural differences across regions.

the crisis. Third, the way consumers perceive the relationship between past behavior and mortality due to nvCJD could trigger this U-shape response. If the dose-response relationship is nonlinear, then the effect of previous consumption could also be nonlinear. This can happen if consumers perceive that beef becomes infectious only beyond a certain threshold.

We present a simple two period model which nests all these different explanations. The model combines habit formation, as in Pollak (1970), and an endogenous life expectancy as in Ehrlich and Chuma (1990). To keep the model simple, we assume a two-stage budgeting, so that the agent allocates total expenditure on animal protein, y, between two goods, beef, c_B, and another composite good, c_o, which represents other types of meat and fish. This choice of modelling is motivated by the empirical evidence in the previous section, which shows that the total expenditure on animal protein did not change as a result of the crisis. We assume that the agent is "born" in period 1 with a stock of beef, S, possibly heterogeneous across agents. This stock has two effects. First, it affects the marginal utility of beef consumption, to capture non-separability over time in preferences. Second, the stock, together with the consumption of beef in period 1, determines the probability of surviving to period 2. The link between beef consumption and mortality takes into account coronary heart problems or nvCJD. We write the probability of survival as $\pi(S + c_B; \kappa)$, where κ parameterizes the perceived effect of the stock of beef on the probability of survival. Consumers base their optimal choice of consumption on this perceived effect. We assume that in the year prior to the crisis, κ was constant, but consumers could have perceived that the effect of beef on health was non zero ($\partial\pi/\partial S \neq 0$). The "Mad Cow" crisis is triggered by an increase in κ when consumers learn about the new risk of nvCJD and adjust their consumption accordingly. In period 2, the agent derives utility from the consumption of both goods and then dies with certainty. The future is discounted by a factor β, possibly heterogeneous across agents, to capture the fact that some individuals care more about the future and would engage less in risky behavior. The program of the agent is then:

$$\max_{c_B, c_o} u(c_B, c_o, S) + \beta\pi(S + c_B; \kappa)V(S + c_B) \tag{1}$$

where $V(S)$ is the flow of future utility, denoted as:

$$V(S + c_B) = \max_{c'_B, c'_o} u\left(c'_B, c'_o, S + c_B\right)$$

where primed variables denote period 2 choices. The optimization in both periods are subject to the budget equation $y = pc_B + c_o$, where p is the relative price of beef.

We assume the usual conditions on the utility function ($u_i > 0$, $u_{ii} < 0$, for $i = 1, \ldots, 3$). We look at comparative statics, by totally differentiating the first order condition. After some straightforward algebra, the change in consumption can be expressed as:

$$\Delta c_B = A_p\Delta p + A_y\Delta y + A_S\Delta S + A_\kappa\Delta\kappa \tag{2}$$

Details of the computation can be found in the Appendix. The change in consumption is related to changes in relative prices, changes in total expenditures, changes in the stock and to changes in the perception of the effect of beef on health. Standard assumptions on the shape of the utility function allow one to sign the effect of several variables: an increase in prices decreases consumption ($A_p < 0$); an increase in total expenditure increases the consumption of beef, unless beef and other protein goods are strong complements. The effect of the stock of beef (A_S), as well as the effect of additional health information (A_κ) have an ambiguous effect (see the derivation in the Appendix). In particular, they depend on the shape of the survival probability through its second derivatives. If for a given level of the stock, consumers perceive that the marginal risk has not changed as a result of the crisis, then $A_\kappa = 0$: the agents keep their consumption level at pre-crisis levels (conditional on prices, total expenditure and past behavior). If the marginal mortality risk increases in absolute value, then the agents reduce their consumption compared to pre-crisis levels. Hence, the model predicts heterogeneous responses in consumption, which depends on prior exposure.

The effect of the first three variables (prices, total expenditure and previous consumption) can be identified from pre-crisis data. The effect of new health information can be identified with data before and after the crisis.

The identification strategy is to interact a dummy equal to one at the time of the crisis with a function of the stock, controlling for changes in prices, in total expenditure and in the stock. The effect of the stock, *at the time of the crisis*, reveals how the agents perceived the change in the marginal mortality risk.

The discussion so far assumes that the weight on future utility, β, is constant in the population. It is possible that there is some heterogeneity in the value for the future and that this value is correlated with the consumption of beef before the crisis. We assume that the rich set of controls we use in the empirical section is enough to capture this effect. We interact these characteristics with a dummy at the time of the crisis to capture their specific effect when new information on health risks is released.

2.2 Econometric specification

The model in the previous section suggests an estimation strategy based on panel data describing consumption before and after the crisis. Denote the consumption of beef for household h in period t as $c^h_{B,t}$. The period length is a quarter. We model the change in behavior for household h as:

$$\begin{aligned}\Delta c^h_{B,t} &= \gamma_1 \Delta \ln p^h_t + \gamma_2 \Delta \ln y^h_t + \gamma_3 \Delta S^h_{B,t} + \gamma_4 X^h_t \\ &\quad + IC_t \left(\gamma_5 + \gamma_6 S^h_t + \gamma_7 S^{h2}_t + \gamma_8 X^h_t\right) + \varepsilon^h_t \end{aligned} \tag{3}$$

As the model is expressed in differences, we implicitly allow for heterogeneity in preferences through a fixed effect. The panel data allows us to abstract from unobserved tastes for beef across households that are correlated with previous exposure.

Consumption also depends on prices, p_t^h, and total expenditure on animal protein, y_t^h. We also allow the *change* in consumption to depend on a range of demographic variables (X_t^h) which capture differences in occupation, education, household composition, region of living, size of the city, other risk taking behavior and seasonal dummies. A second important feature of the model is that we allow for state dependence through the "stock" of past health behavior, S_t^h. This term will capture habit formation or adjustment costs that may prevent individuals with high consumption from reducing their consumption level when faced with higher prices or when they learn about the health consequences of nvCJD.

In a cross-section it is evidently impossible to identify state dependence from the disease susceptibility as they both relate to past behavior and are captured by the coefficient γ_3. However, the change in consumption due to the crisis identifies the change in the perception of the disease susceptibility, over and above the effect of state dependence present in all periods. The identification of both effects requires that consumers were unaware before March 1996 of a link between beef consumption and nvCJD susceptibility. We identify the effect of new health information by the dummy variable IC_t which takes a value of zero until March 1996. We interact this dummy with prior exposure to beef to proxy for nvCJD susceptibility. This term captures the specific effect of disease susceptibility at the time when consumers learn about the risk of infection. We also allow for (observed) heterogeneity in the response to new health information, which could be correlated with prior exposure. This will help to control for heterogeneity in other risk taking attitudes as well as perceived regional differences in the prevalence of BSE. We use as a proxy for the stock the average per capita quantity of beef consumed between January 1995 and January 1996. This variable is measured in grams per week per person. Equation 3 can be simplified by noting that $\Delta S_{B,t}^h = c_{B,t-1}^h$.

As is commonly done in the applied demand literature (see for instance Nichèle and Robin 1995) we estimate the model using instrumental variables to control for a possible correlation between ε_t^h and $c_{B,t-1}^h$ and the endogeneity of total expenditure. We use as instruments lagged prices and lagged total expenditure.[8]

3 Results

The estimation results are displayed in Table 3, columns 1 to 3. Column 1 displays the results for the entire sample, column 2 for single person households and column 3 for households with at least two members. We discuss the results below.

[8]The first stage indicates that the instruments have power with F tests with associated p values of 0 for all endogenous variables.

Table 3 Determinants of change in consumption

	All households	Single person households	All households size≥2	All households pre-crisis only
Past beef consumption	−0.07* (0.04)	−0.04 (0.04)	−0.05 (0.05)	−0.06 (0.04)
Stock of beef × quarter of crisis	−0.36** (0.11)	−0.46** (0.10)	−0.34** (0.09)	0.14* (0.07)
Squared stock × quarter of crisis	0.45* (0.24)	0.33** (0.06)	0.42** (0.14)	−0.07 (0.06)
Δ log total expenditure	103.0**(16.2)	92.55** (19.8)	108.50** (8.77)	114.01** (15.35)
Δ log price	−17.1 (93.0)	−135.20 (280.9)	−1.19 (29.07)	−231.44* (1143.55)
Size of household	−0.10 (1.52)			0.89 (1.80)
Size of household × quarter of crisis	9.5** (3.9)			−3.13 (3.01)
Number age [0,4] × quarter of crisis			0.21 (11.23)	
Number age [4,9] × quarter of crisis			−3.82 (8.81)	
Number age [10,18] × quarter of crisis			−0.63 (6.79)	
Number males [10,18] × quarter of crisis			20.04** (9.77)	
Age of head	0.18 (0.15)	0.52 (0.37)	0.18 (0.36)	0.15 (0.18)
Age of head × quarter of crisis	−0.53* (0.3)	−0.88 (0.62)	−0.81 (0.55)	−0.08 (0.26)
Body mass low	1.25 (4.85)	0.64 (41.1)	−1.46 (6.35)	1.95 (5.68)
Body mass medium	4.12 (4.2)	6.23 (11.2)	−0.79 (5.19)	3.88 (5.20)
Body mass low × quarter of crisis	−19.0** (9.9)	7.94 (81.2)	−12.34 (17.18)	−0.58 (10.11)
Body mass medium × quarter of crisis	−20.3** (8.9)	−31.70 (22.1)	−7.95 (15.35)	1.21 (8.14)
Alcohol low	0.57 (4.7)	6.78 (14.3)	−0.24 (7.20)	7.70 (5.44)
Alcohol medium	2.55 (4.0)	15.58 (13.9)	2.13 (4.60)	5.34 (4.75)
Alcohol low × quarter of crisis	−14.5* (8.8)	−3.43 (23.6)	−12.37 (12.77)	−15.02 (8.65)
Alcohol medium × quarter of crisis	−16.2* (8.7)	−14.2 (26.0)	−18.61* (10.84)	−5.17 (7.81)
Number of observations	9,473	1,449	8,024	7,106
R^2	0.21	0.24	0.25	0.20
Over identification test $\chi^2(4)$ (p val)	2.17 (0.54)	0.45 (0.93)	0.22 (0.97)	2.17 (0.54)

Robust standard errors in parentheses. The regression also controls for occupation, education level, nationality, seasonal dummies, region of living and size of city. Two stage least squares estimates. Instruments: one lag of prices and total expenditures, two lags of prices, total expenditures to instrument lagged consumption and stock.

*Significant at 10%.

**Significant at 5%.

3.1 Effect of past consumption

As in Section 1.4, the effect of previous exposure to beef, at the time of the crisis, is nonlinear and U-shaped and comes out statistically significant. It is indeed one of the most precisely estimated coefficients. Similar results are obtained for single households only. The coefficients on the stock of beef and its square indicate that consumption declines for weekly averages between 0 and 400 g and increases after that. The maximum decrease is about 70 g. For singles, the decrease is more pronounced and can be up to 160 g. We also find some evidence of habit formation. An increase in the consumption of beef of one gram decreases the consumption of beef by 0.07 g. For singles, the effect is lower (a reduction of 0.04 g) and we cannot reject that this effect is equal to zero.

These results are obtained despite controlling for habit formation, prior risky habits, as well as differences in taste, education, occupation and geographic location. They show that individuals perceive the marginal mortality risk to vary with the level of prior exposure. The perceived marginal risk of further beef consumption appears to be lower both at lower and higher levels of exposure.

3.2 Socio-economic determinants

Prices do not come out statistically significant, because we are relying on (moderate) time and regional variations. However, the results suggests that higher prices reduce the consumption of beef as predicted in Section 2.1. The effect of total expenditure on animal protein on expenditures on beef is very precisely estimated as we have variations across households and time. A one percent increase in total expenditure increases the consumption of beef by 1.03 g. Households with an overweight head reduced their expenditure by about 20 g less during the crisis. Alcohol consumption does not appear to be correlated with the change in behavior at the time of the crisis.

The regression also controls for size of city, region of living, education and occupation (results not shown, but available upon request). At the time of the crisis, the geographical location, education and occupation do not appear to influence further consumption choices as we cannot reject that they have no effect. Households living in rural areas decreased their consumption less than those in large cities, by about 22 g per week. This might reflect a difference in information on local prevalence of BSE.

The coefficient of the age of the head of the household is statistically significant and negative at the time of the crisis. Each additional year of age decreases beef consumption by 0.5 g, although the effect is only significant at the 10% level. It is somewhat surprising that older individuals decrease their consumption more as CJD takes several years to incubate, so one would expect older individuals to respond less to the crisis. One reason might be that the new variant CJD has a shorter incubation time (even teenagers have died from the disease). The second reason could be that older individuals, although closer to their life horizon, become increasingly cautious. The size of the household affects the behavior during the crisis, with larger households reducing their consumption less. Each additional individual in the household leads to a reduction of 9 g per week. We analyze the effect of the composition of the household in more detail in the next section.

3.3 Household behavior

Table 3 column 3 displays the effect of the crisis for households with at least two individuals. We augment the regression model with variables describing the household composition in terms of age and sex of children (the regression results in columns 1 and 2 already control for the age and sex of the head of household).

The number of infants of age 0 to 4 have little effect on how the households responded to the crisis. This is true as well for the next age group (5 to 9). However, the number of children of age 10 to 17 comes out strongly if these are males. Each additional male of that age group increases consumption by 20 g. Conversely, we find no effect of girls in that age group.[9]

These results indicate that families with teenagers are more reluctant to change their behavior. Several reasons could be put forward. First, children eat less than adults and would have lower exposure than their parents. Given the U-shape response, the presence of family members less exposed to beef consumption could attenuate the response of the family leading to an "aggregation" bias. However, girls probably eat less than boys, so one would expect families with teenage girls to reduce their consumption less, which we do not observe.

Second, it might be the case that families with children in that age group are less prone to switch from beef to other types of protein, even before the crisis. Parents might think that beef is important for the well being of teenagers and that this concern outweighs the concern about nvCJD. This could be seen as a "cost" of adjusting the consumption of beef which depends on the presence of children. Given that we observe the behavior of these households for more than a year before the crisis, we are actually able to evaluate the importance of this "cost of adjustment." If adjusting consumption levels is more costly for families with children, they should be reluctant to change the consumption of beef following a change in prices or in total expenditure as well. This would also be true before the crisis. We investigate whether families with teenagers have lower demand elasticities before the crisis, which would suggest that these households are less susceptible to switch from beef to another category of meat or fish. We computed the total expenditure elasticity by estimating a demand system for beef and for all other types of animal protein. The total expenditure elasticity for beef is 1.05 (0.01) for all

[9]We do not find statistical evidence of gender differences for younger children.

households and 1.01 (0.30) for households with teenagers. The latter elasticity is not estimated very precisely, given the smaller number of observations, so we cannot reject a different elasticity for these families. Moreover the point estimates are quite close. We also computed this elasticity for households with younger children and found a total expenditure elasticity of 1.02 (0.03).

Before the crisis, families with teenagers did not appear to have a rigid diet. They were as likely as others to substitute to other types of meat in response to changes in total expenditures. The reason for this rigidity must come from the nature of the crisis itself. One explanation could be that teenagers were less concerned about the health consequences associated with beef consumption than other age groups. This may indicate that this age group has a lower discount rate, especially for boys. That young males engage in risky habits and care less for their future health has been documented in the literature before (see Gruber 2001 for instance). At that age, a number of them start smoking, experiment with drugs and drive motorcycles.

What is more surprising is that teenagers affect the behavior towards health risks of the whole household. It is doubtful that children of that age gof out and buy beef on their own. This means that they must influence their parents into buying a potentially unsafe product. The literature on intra-household behavior usually emphasizes the role of the distribution of resources within the family or of threat points in explaining the bargaining power of individual members, as in McElroy (1990), Browning and Chiappori (1998) or Bourguignon (1999). As teenagers have virtually no income and cannot split from the household, these models would predict that they have no bargaining power. Yet, they appear to have an influence on household behavior towards risks.[10]

3.4 Demand for quality

The model presented in Eq. 3 considered beef as a homogenous good. In reality, beef comes in many different cuts and quality, so the consumer has not only a decision to make about the quantity but also on the quality.

Figure 3 shows how consumers responded in the quality dimension. Table 4 presents a regression of the change in quality (as measured by the price in euros per gram) on the previous exposure to beef using a number of control variables. The regression also controls for past behavior and regions of living, size of city, occupation, education, family size and income. Individuals with low exposure (below the first quintile of the distribution) or with high exposure (above the last quintile) did not change their behavior in terms of quality. Consumers in the middle of the distribution of prior exposure to beef bought cuts of beef that are more expensive (0.29 euros per gram). The second column

[10] However, the fact that parents cannot split from their teenagers gives these children some bargaining power.

Table 4 Effect of previous exposure to beef on changes in the demand for quality

Variable	During crisis estimate	Before crisis estimate
Stock of beef, lowest quintile	0.001 (0.21)	0.12 (1.1)
Stock of beef, second quintile	0.29* (.15)	−0.06 (0.8)
Stock of beef, third quintile	0.29** (0.14)	0.04 (0.6)
Stock of beef, fourth quintile	0.06 (0.12)	−0.03 (0.5)
Number of observations	2,346	7,439
R^2	0.18	0.21

Heteroscedastic corrected standard errors were computed. Regression also controls for lagged changes in quality, region of living, size of city, occupation, education, family size and income.

*Significant at 10%.

**Significant at 5%.

of Table 4 shows that this was not the case before the crisis, where prior exposure was not correlated with demand for quality.

3.5 Robustness of results

To check the robustness of the results, we estimate Eq. 3 on pre-crisis data only, pretending the crisis took place in the first quarter of 1996 (IC_t takes a value of one at that date). The last column of Table 3 displays the results. The coefficients in front of the stock of beef are reduced by a factor 3 at least, and insignificant at any conventional level. The sign of the effect is also reversed. This shows that the behavior of the households is being influenced by previous quantities, *once* the crisis is known. It is hard to find a reason based on measurement errors, misspecification or endogeneity which would explain why the previous exposure to beef comes out statistically significant for one quarter and not the other. This means that the change in behavior is directly linked to the crisis.[11]

We also checked whether the effect of prices and of total expenditure changed as a result of new information. This is possible as we have not only time but also spatial variations in prices and expenditures. We found no significant effects and the remaining results were robust to these changes.

We also checked that the U-shape pattern is real and not an artifact of the quadratic function imposed in the econometric specification. We used ten dummy variables for the size of the stock at the time of the crisis and found a similar effect.

Finally, in model 3, the habit formation was modelled as a monotonic and increasing function of past behavior. In this specification, consumers with high level of prior exposure would respond less to the crisis. However, one could

[11] We also estimated a tobit model which takes into account the truncation at zero, as expenditures cannot be negative. Consumers with a small stock might have little scope to reduce their consumption, which might explain why they respond less to the crisis. We found that the results are comparable to the one in Table 3.

Table 5 Price and total expenditure elasticities, prior to the crisis

Stock quintile	[0, 20%]	[20%, 40%]	[40%, 60%]	[60%, 80%]	[80%, 100%]	All
Price elasticity	−1.46**	−1.9**	−1.74**	−1.22**	−1.33**	−1.37**
Standard dev.	(0.44)	(0.25)	(0.19)	(0.18)	(0.13)	(0.09)
Total expenditure elasticity	0.93**	0.67**	0.79**	0.85**	0.95**	1.05**
Standard dev.	(0.03)	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Number of observations	2,774	2,797	2,804	2,803	2,804	13,982
R^2	0.03	0.20	0.15	0.12	0.06	0.003

Estimations performed on data prior to the crisis. An individual fixed effect was included.

*Significant at 10%.

**Significant at 5%.

think of a more general pattern where consumers with both high and low exposure to beef could face a high cost of adjustment. Habit formation could be important for high stock consumers. On the other side of the spectrum, low stock consumers could have a taste for variety, which makes reducing or stopping the consumption of beef difficult for them.[12]

The hypothesis of a nonlinear cost of adjustment can be tested on the pre-crisis data. If individuals face different costs of adjustment, they should also react differently to price or total expenditure changes. In the event of an increase of prices or of total expenditures, these consumers should react less in the short run and should therefore have lower price and total expenditure elasticities (in absolute values). The idea is to check whether price or total expenditure elasticities differ between households with different pre-crisis levels of consumption, *before* the crisis.

The elasticities are estimated on pre-crisis data, by fitting an almost ideal demand system (Deaton and Muellbauer 1980). Five independent regressions are run for each quintile of the stock. The regression uses the panel structure and allows for a fixed effect in levels. Total expenditure is instrumented by income and lagged expenditures. The results are displayed in Table 5.

The price elasticities range between −1.9 to −1.22, without any clear gradient. In fact, given the standard errors, the elasticities for each quintile are not significantly different from the overall elasticity. The total expenditure elasticities range between 0.67 to 0.95. As they are more precisely estimated, the elasticities are different across groups. However, the groups which have the highest elasticities are the ones with the lowest and the highest prior exposure to beef. If anything, the low and high stock consumers appear to be more willing to adjust their consumption to total expenditure or price movements. When the crisis comes along, they should be able to decrease their consumption more than average, but the data suggests the opposite. Hence, heterogeneous adjustment costs do not explain the features found in Section 1.3.

[12]We are grateful to W. Kip Viscusi for suggesting this point.

4 Discussion and conclusion

Previous studies on health behavior, especially on tobacco consumption, show that individuals are aware of the risks in a surprisingly accurate way (Viscusi 1990 or Antoñanzas et al. 2000). Studies on expected longevity also reveal that individuals correctly evaluate the consequences of health behavior decisions on their life expectancy (Hurd and McGarry 1995; Hurd, MacFadden and Merrill 2001 or Hurd and McGarry 2002). The contribution of this paper is to show how new information translates into actual health behavior, disentangling the effect of selection, state dependence and unobserved preferences.

We find that many forces shape the response to new health information. We find that habit formation plays a role, as well as the composition of the household. While habit formation, or addiction, has been widely studied in relationship with public intervention—for instance in the case of tobacco—the second factor is much less well understood. This is a very difficult topic to address usually given the lack of clear exogenous variation in risk. Few papers have attempted to investigate this issue. A notable exception is Khwaja, Sloan and Chung (2006) who investigate the effect of marital status on smoking decisions using panel data from the Health and Retirement Survey. Little is known or documented on how a group of individuals decide collectively about health risks. Yet, most of the risk taking behavior involves not only the individual himself, but also other surrounding family members. Acknowledging that risk taking behavior at the household level is not just the sum of individual behavior is important to guide the implementation of policy making. Clearly more research and evidence is needed in this field, but this paper takes a step towards it.

The main contribution of the paper is to show that behavior appears also to be driven by another important factor, the perception of the marginal effect of further risky behavior on health. It results in modest and substantial beef consumers reducing their consumption less than moderate consumers. Consumers both at low and high risk engaged in further risky behavior, once the link between consumption of beef and nvCJD was made public.

This finding has consequences for our understanding of health behavior and how they should be modelled. Starting with the seminal paper by Becker and Murphy (1988), the literature on substance abuse has concentrated mainly on the dynamic implication of addiction, but not on how further consumption influences the marginal mortality risk.[13] Part of the dynamics uncovered in empirical applications may stem from this source and not entirely from non-separable preferences. However, this effect is difficult to identify in the absence of an exogenous change in risk perception.

The “Mad Cow” scare also provides a natural experiment to evaluate how individuals would react, in a broader context, to new information on disease susceptibility. The discovery of nvCJD is one of many cases where individuals learn that they are at risk from their past behavior (the link between tobacco

[13]Becker and Mulligan (1997) discuss the case of an endogenous discount factor.

and health by the Surgeon General in 1964 is an early example). In the future, the implementation of genetic testing, which would make it possible to test for the susceptibility of contracting diseases such as lung cancer, cardiovascular diseases or diabetes, could lead to similar dynamic behavior. From a public health perspective, it is important to acknowledge that new information about health risks does not lead to a uniform decline in risky behavior. This is not only due to heterogeneity in preferences which are correlated with risky behavior, but stems from the perceptions individuals have of their prior exposure.

Appendix

The first order condition of model 1 is:

$$u_1 - pu_2 + \beta\pi_1 V + \beta\pi V_1 = 0$$

where u_i and V_i denote the partial derivative of the utility function and second period indirect utility function with respect to the ith argument. First differentiating this expression gives:

$$\begin{aligned}\Delta c_B[u_{11} - 2pu_{12} + \beta V\pi_{11} + 2\beta\pi_1 V_1 + \beta\pi V_{11}] + \Delta y[u_{12} - pu_{22}] \\ + \Delta p[-cu_{12} - u_2 + pcu_{22}] + \Delta S\left[u_{13} - pu_{23} + \beta\pi_{11}V + 2\beta\pi_1 V_1 + \beta\pi V_{11}\right] \\ + \Delta\kappa\beta\,[V\pi_{12} + \pi_2 V_1] = 0\end{aligned}$$

which can be written more compactly as:

$$\tilde{A}_B\Delta c_B + \tilde{A}_y\Delta y + \tilde{A}_p\Delta p + \tilde{A}_S\Delta S + \tilde{A}_\kappa\Delta\kappa = 0$$

so that:

$$\Delta c_B = A_p\Delta p + A_y\Delta y + A_S\Delta S + A_\kappa\Delta\kappa$$

Standard restrictions on the shape of the utility function imply that $u_i > 0$, $u_{ii} < 0$, $V_i > 0$, $V_{ii} < 0$. Moreover, the definition of the survival probability implies that $\partial\pi(S,\kappa)/\partial S = \pi_1 \leq 0$ and that $\partial\pi(S,\kappa)/\partial\kappa = \pi_2 \leq 0$, if individuals perceive that nvCJD is a threat to life.

If $u_{12} \geq 0$ (beef and other meat products are complements) and the relationship between survival and beef consumption is concave ($\pi_{11} \leq 0$, then $\tilde{A}_B \leq 0$, $\tilde{A}_p \leq 0$ and $\tilde{A}_y \geq 0$. The effect of health information on consumption of beef is equal to:

$$A_\kappa = \left(-\frac{\beta}{\tilde{A}_0}\right)(V\pi_{12} + \pi_2 V_1)$$

References

Adda, Jérôme and Francesca Cornaglia. (2006). "Taxes, Cigarette Consumption and Smoking Intensity," *American Economic Review* 96(4), 1013–1028.

Antoñanzas, Fernando, W. Kip Viscusi, Joan Rovira, Francisco J. Braña, Portillo Fabiola, and Iirineu Carvalho. (2000). “Smoking Risks in Spain: Part I Perception of Risks to the Smoker,” *Journal of Risk and Uncertainty* 21(2/3), 161–186.
Becker, Gary S. and Casey B. Mulligan. (1997). “The Endogenous Determination of Time Preference,” *Quarterly Journal of Economics* 112(3), 729–758.
Becker, Gary S. and Kevin M. Murphy. (1988). “A Theory of Rational Addiction,” *Journal of Political Economy* 96(4), 675–699.
Bourguignon, François. (1999). “The Cost of Children: May the Collective Approach to Household Behavior Help?” *Journal of Population Economics* 12(4), 503–521.
Browning, Martin and Pierre-André Chiappori. (1998). “Efficient Intra-Household Allocations: A General Characterization and Empirical Tests,” *Econometrica* 66(6), 1241–1278.
Chesher, Andrew. (1997). “Diet Revealed? Semiparametric Estimation of Nutrient Intake-Age Relationships,” *Journal of the Royal Statistical Society* 160(3), 389–428.
Deaton, Angus and John Muellbauer. (1980). “An Almost Ideal Demand System,” *American Economic Review* 70(3), 312–326.
Ehrlich, Isaac and Hiroyuki Chuma. (1990). “A Model of the Demand for Longevity and the Value of Life Extension,” *Journal of Political Economy* 98(4), 761–782.
Farrell, Phillip and Victor Fuchs. (1982). “Schooling and Health: The Cigarette Connection,” *Journal of Health Economics* 1, 217–230.
Green, Peter J. and Bernard W. Silverman. (1994). *Nonparametric Regression and Generalised Linear Models: A Roughness Penalty Approach*. London: Chapman and Hall.
Gruber, Jonathan. (2001). “Risky Behavior among Youth: An Economic Analysis.” In Jonathan Gruber (ed), *Risky Behavior Among Youth: An Economic Analysis*. Chicago: University of Chicago Press.
Hurd, Michael, Daniel MacFadden, and Angela Merrill. (2001). “Predictions of Mortality among the Elderly.” In David Wise (ed), *Themes in the Economics of Aging*. Chicago: University of Chicago Press.
Hurd, Michael D. and Kathleen McGarry. (1995). “Evaluation of the Subjective Probabilities of Survival in the Health and Retirement Study,” *Journal of Human Resources* 30(0), S268–292.
Hurd, Michael D. and Kathleen McGarry. (2002). “The Predictive Validity of Subjective Probabilities of Survival,” *Economic Journal* 112(482), 966–985.
Khwaja, Ahmed, Frank Sloan, and Sukyung Chung. (2006). “The Effects of Spousal Health on the Decision to Smoke: Evidence on Consumption Externalities, Altruism and Learning within the Household,” *Journal of Risk and Uncertainty* 32(1), 17–35.
McElroy, Marjorie. (1990). “The Empirical Content of Nash Bargained Household Behavior,” *Journal of Human Resources* 25, 559–583.
Nichèle, Véronique and Jean-Marc Robin. (1995). “Simulation of Indirect Tax Reforms Using Pooled Micro and Macro French Data,” *Journal of Public Economy* 56, 225–244.
Pollak, Robert A. (1970). “Habit Formation and Dynamic Demand Functions,” *Journal of Political Economy* 78(4), 745–763.
Viscusi, W. Kip and Joni Hersch. (2001). “Cigarette Smokers as Job Risk Takers,” *Review of Economics and Statistics* 83(2), 269–280.
Viscusi, W. Kip. (1990). “Do Smokers Underestimate Risks?” *Journal of Political Economy* 98(6), 1253–1269.
Viscusi, W. Kip. (1993). “The Value of Risks to Life and Health,” *Journal of Economic Literature* 31, 1912–1946.
Viscusi, W. Kip. (1997). “Alarmist Decisions with Divergent Risk Information,” *The Economic Journal* 107, 1657–1670.
Viscusi, W. Kip, Welsey A. Magat, and Joel Huber. (1987). “An Investigation of the Rationality of Consumer Valuations of Multiple Health Risks,” *Rand Journal of Economics* 18(4), 465–479.
Viscusi, W. Kip and Michael J. Moore. (1989). “Rates of Time Preference and Valuations of the Duration of Life,” *Journal of Public Economics* 38, 297–317.